Technical University of Denmark

Prediction of Solar Heating Plant Performance

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Prediction of Solar Heating Plant Performance

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Introduction

- Denmark's goal is to be CO_2 neutral in 2050
- More and more renewable energy
- >39% wind power in 2014
- >60% District heating (DH)
- >44% of DH supplied by biomass

Solar heating in Denmark

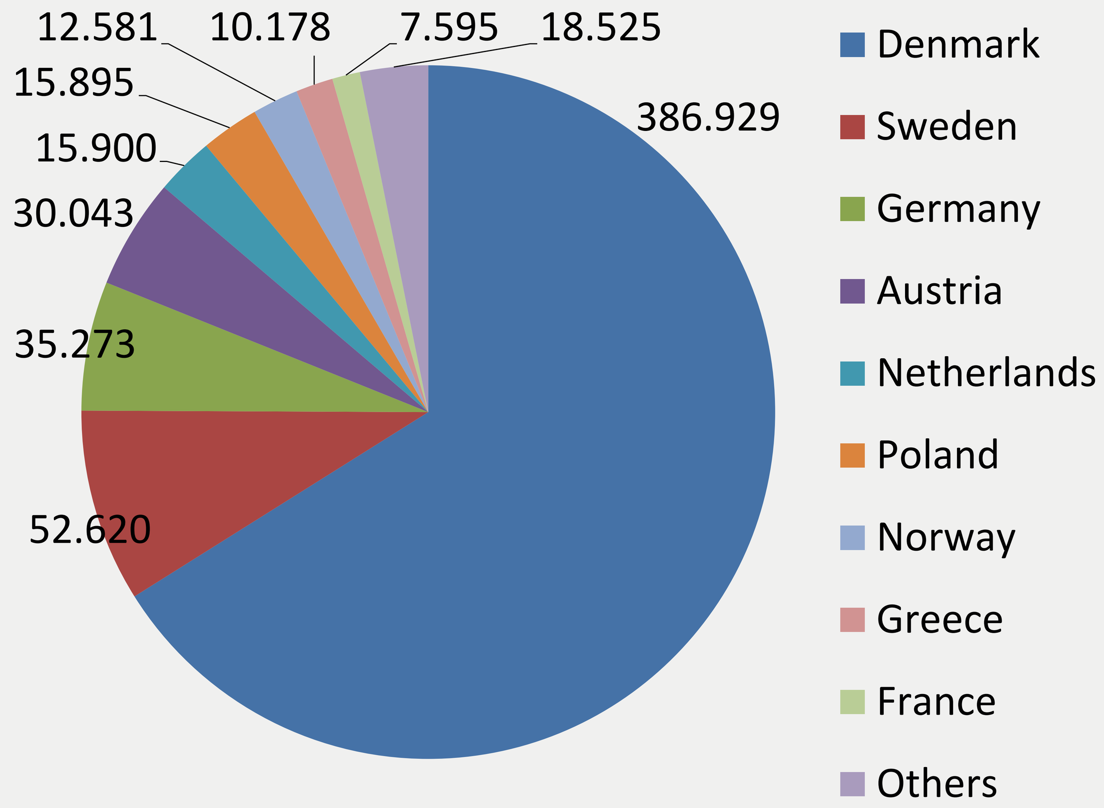


Fig 1: Installed solar collector area in EU in 2014 [m²]

Facts:

- 585,539 m² in EU, 66% in DK
- 14 out of 16 plants >10,000 m² in DK
- 1.3 mio m² in 2016 in DK
- Economy of scale → build large

Problem of many renewables:

- Depending on weather conditions
- Difficult to predict
- System imbalances
- Fluctuations of power prices

Solution:

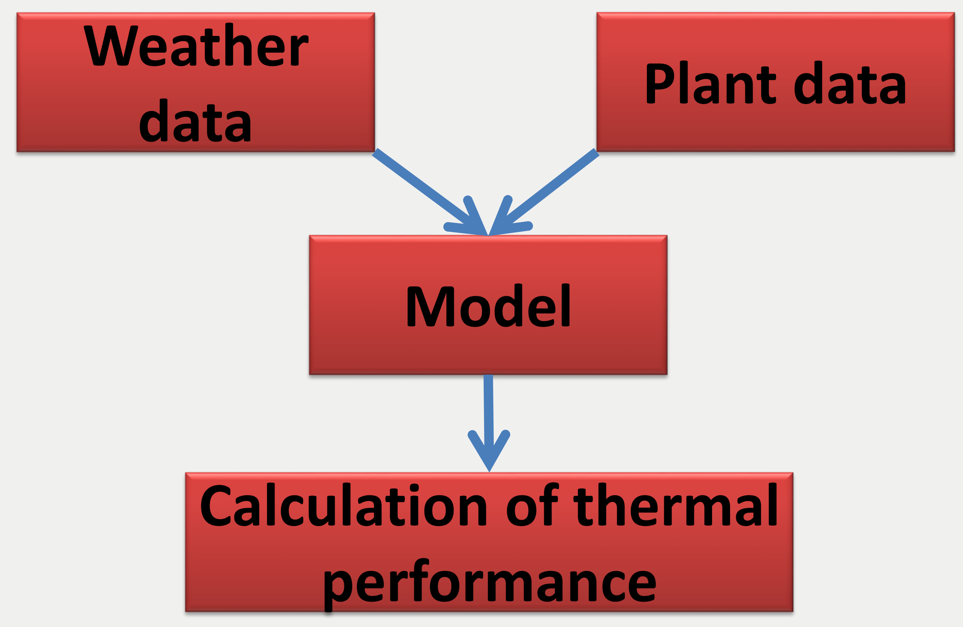
- Improve forecasts of generating power and heat from renewables:
- Objective:

Predict thermal performance of large scale solar heating plants

Reference plant:

- Gram, 802 collectors, 10,000 m²

Method



What you need:

- Weather data: solar irradiation, wind speed and ambient temperature
- General plant data: location, size, orientation, tilt, collector type, etc.

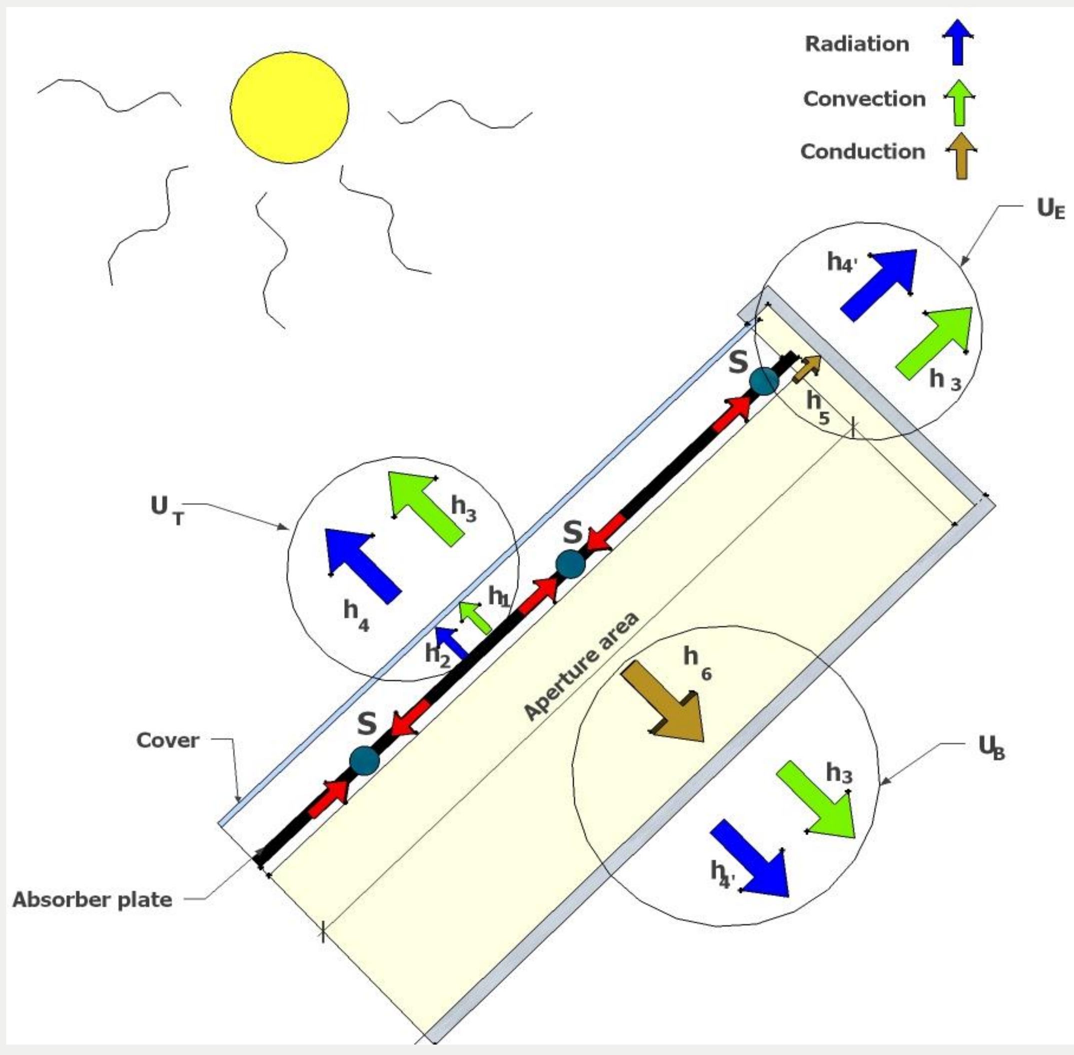
What you get:

- Energy output, outlet temperature and volume flow rate

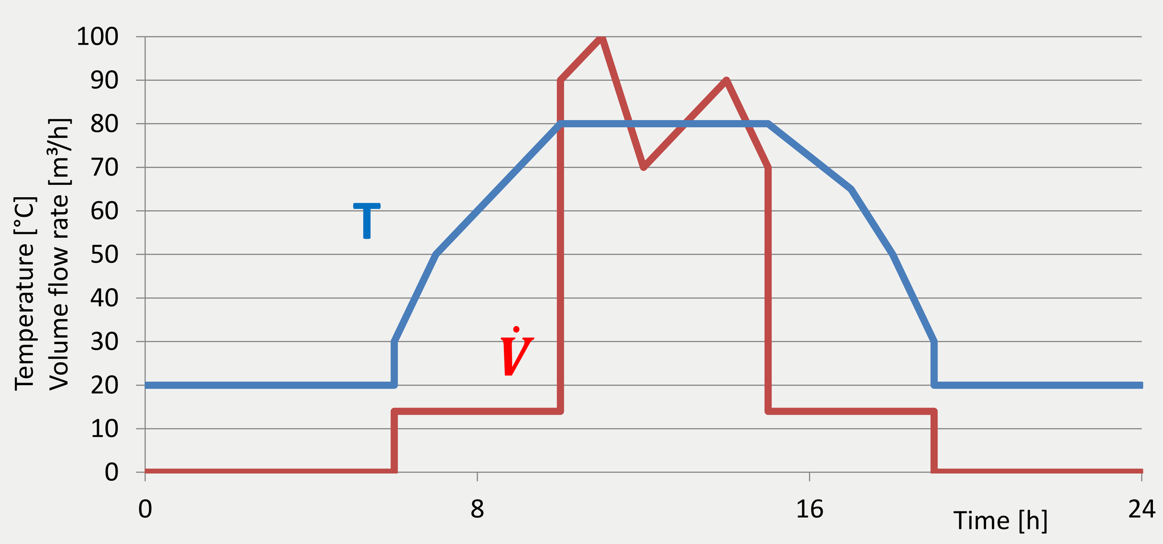
Model characteristics:

- Calculations based on basic heat transfer instead of efficiency expression

$$\cancel{\eta = \eta_0 - a_1 \frac{(T_m - T_a)}{G_{Sun}} - a_2 \frac{(T_m - T_a)^2}{G_{Sun}}}$$



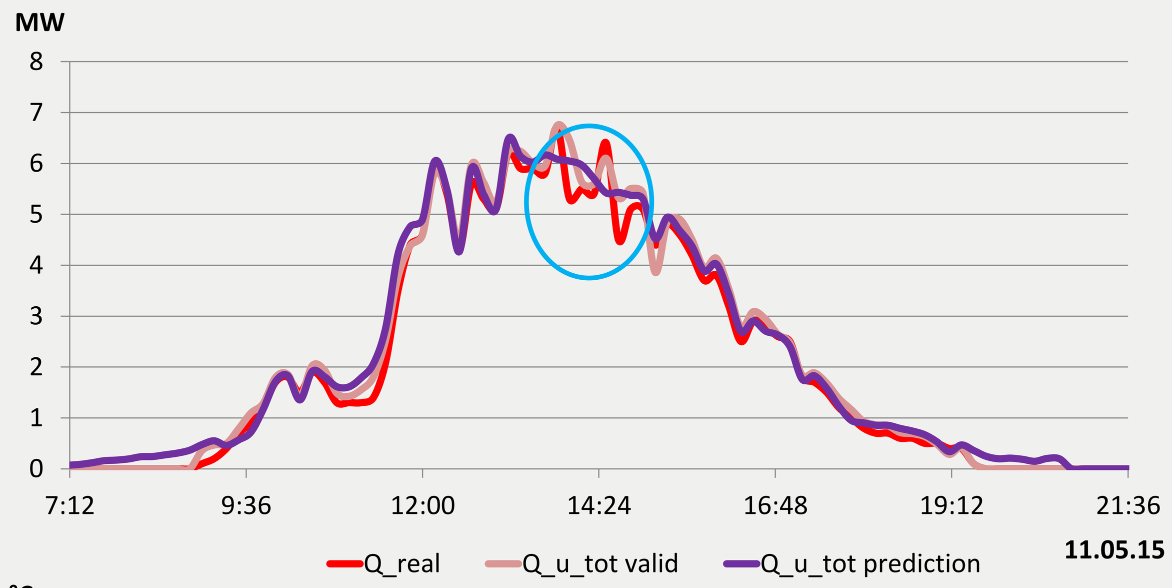
- More complicated calculations, but accurate in off-design conditions
- Inlet temperature adjusted based on previous day
- Model chooses between:
  → Minimum volume flow rate $\dot{V}_{min}$
  → Maximum outlet temperature T_{max}

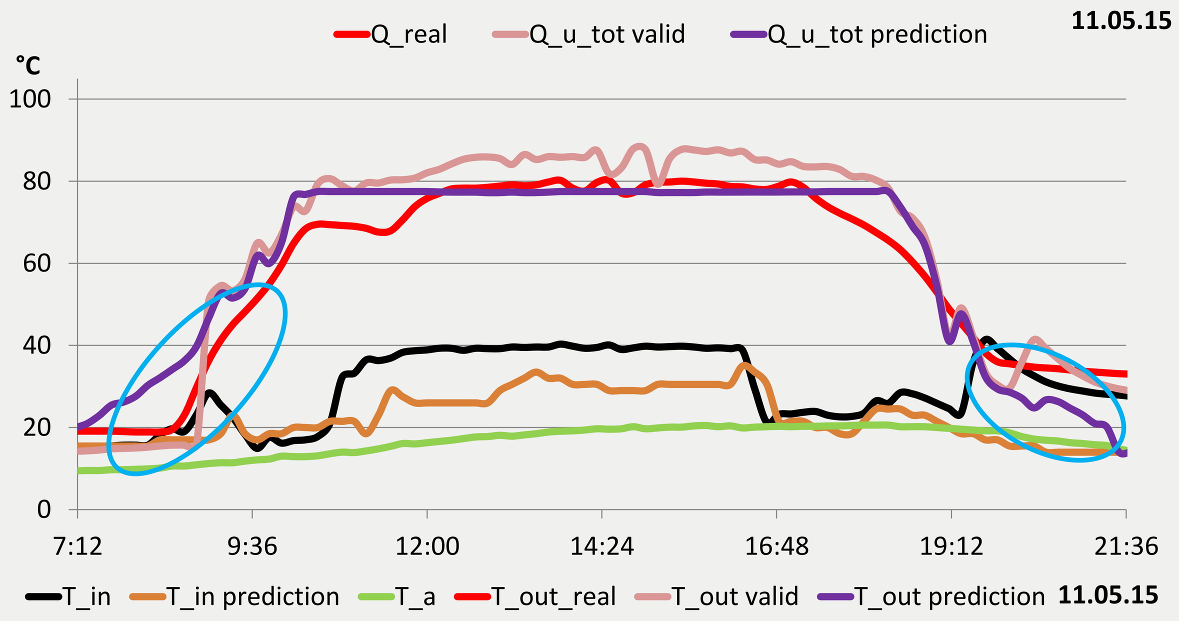


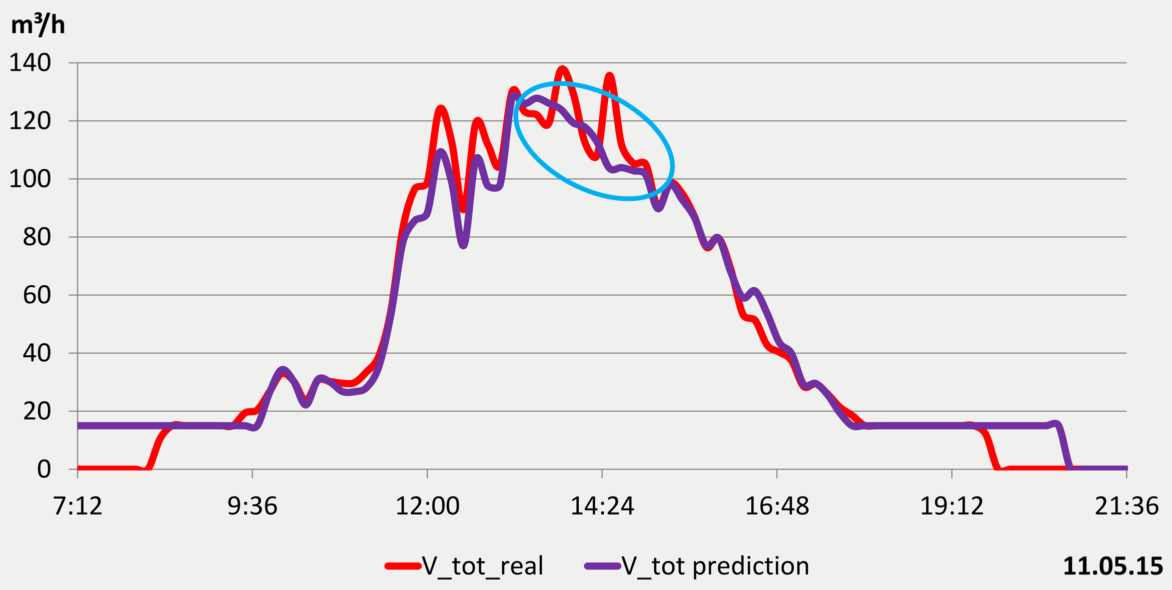
Results & conclusion

- Entire plant modelled by single collector
- Constant time delay of 40 min to represent system inertia of the plant
  → Heat capacity of material
  → Running time of fluid through plant
- Validation based on reference plant using measured irradiation on the collector tilt, volume flow rate and inlet Temperature

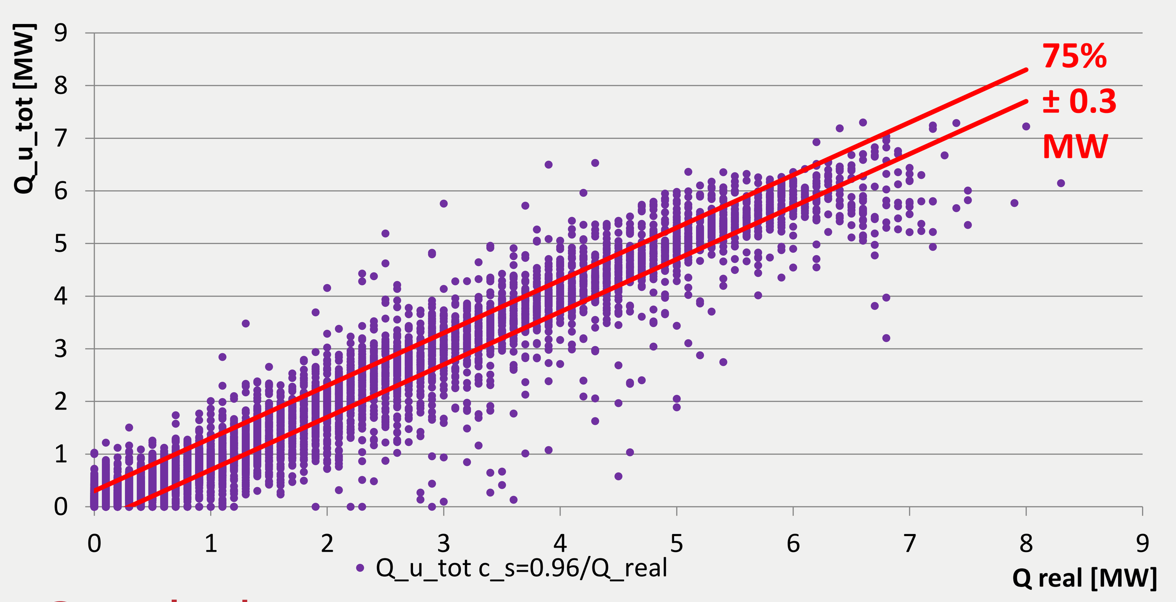
Example of 11.05.2015:







Calculated vs. measured energy output:



Conclusion:

- Prediction of thermal performance possible
  → Reduced heat supply
  → Higher flexibility and stability
- Applicable for any location, plant and time
- Compatible with energy system optimization tools like Mentor Planner

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